

2014  
WESTERN SOUTH DAKOTA  
HYDROLOGY MEETING

Program and Abstracts

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**April 9, 2014**  
**Rushmore Plaza Civic Center**  
**Rapid City, South Dakota**

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# **2014 Western South Dakota Hydrology Meeting**

This program and abstracts book has been produced in conjunction with the 2014 Western South Dakota Hydrology Meeting (12<sup>th</sup> annual), held at the Rushmore Plaza Civic Center on April 9, 2014. The purpose of this book is to provide summaries of the presentations made during the meeting.

The purpose of the 2014 Western South Dakota Hydrology Meeting is to bring together researchers from Federal, State, University, local government, and private organizations and provide a forum to discuss topics dealing with hydrology in western South Dakota. This meeting provides an opportunity for hydrologists, geologists, engineers, scientists, geographers, students, and other interested individuals to meet and exchange ideas, discuss mutual problems, and summarize results of studies. The meeting consists of four technical sessions, several keynote speakers, the John T. Loucks Distinguished Lecture, and a poster session. The topics of the technical sessions include integrated water-resources management, ecosystems, in-situ mining issues, climate and stormwater, anthropogenic effects of water resources, groundwater, hydrologic extremes, and hydrogeologic characterization and erosion.

## **ACKNOWLEDGMENTS**

Many people have contributed to this meeting. The many presenters are thanked for their contributions. The moderators are thanked for their help in streamlining the technical sessions. The help by many students from the South Dakota School of Mines and Technology with presentations and lights is greatly appreciated. The distinguished lecturer, Dr. Tom Loveland, is thanked for his time and perspectives. Keynote speaker Dr. Michael Campana is thanked for his time and perspectives. Registration help by Sheri Meier (USGS) and Denise Livingston (West Dakota Water Development District) is greatly appreciated. Josh Lee (USGS) provided computer support for the meeting.

The organizing agencies are thanked for support: National Weather Service, South Dakota Department of Environment and Natural Resources, South Dakota School of Mines and Technology, U.S. Geological Survey, and West Dakota Water Development District. The West Dakota Water Development District is thanked for sponsoring the John T. Loucks Distinguished Lecture. RESPEC Water & Natural Resources is thanked for being the Executive Sponsor. The many vendors are thanked for their support of the conference. TransCanada is thanked for sponsoring the morning break. WWC Engineering is thanked for sponsoring the evening social. The chairpersons for this meeting were Melissa Smith (National Weather Service), Lacy Pomarleau (RESPEC), Joanne Noyes (South Dakota Department of Environment and Natural Resources), Bora Cetin (South Dakota School of Mines and Technology), Arden D. Davis (South Dakota School of Mines and Technology), Scott J. Kenner (South Dakota School of Mines and Technology), Kelli McCormick (South Dakota School of Mines and Technology), J. Foster Sawyer (South Dakota School of Mines and Technology), Mark T. Anderson (U.S. Geological Survey), Janet M. Carter (U.S. Geological Survey), and Daniel G. Driscoll (U.S. Geological Survey).



The Western South Dakota Hydrology Conference plays an integral role in communicating the importance of our natural resources. RESPEC is honored to have been a sponsor of this conference over the past decade. Our sincere gratitude goes out to all the presenters and attendees that have made this conference so valuable. We look forward to continuing to support this important endeavor.

Thank you from the RESPEC family!

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# 2014 WESTERN SOUTH DAKOTA HYDROLOGY MEETING PROGRAM

**Thursday, April 9, 2014**  
**Alpine/Ponderosa Rooms and Rushmore F and G**  
**Rushmore Plaza Civic Center**

7:00 – 8:00 a.m.	REGISTRATION		
8:00 – 10:00 a.m.	Plenary Session 1 in Alpine and Ponderosa Rooms – 2014 Theme: Integrated Water-Resources Management (2.0 PDH) Moderator – Mark Anderson, U.S. Geological Survey		
8:00 – 8:10 a.m.	Welcome, general information	Mark Anderson and Daniel Driscoll, U.S. Geological Survey	
8:10 – 8:40 a.m.	Invited presentation: A perspective on paleoclimate, historical climate, and projected climate	John Stamm, U.S. Geological Survey	
8:40 – 9:20 a.m.	Mongolia: Integrating cultures, people, and research	Scott Kenner, South Dakota School of Mines and Technology	
9:20 – 10:00 a.m.	Keynote presentation: Integrated water-resources management—The emperor’s new clothes or indispensable process?	Michael E. Campana, Oregon State University	
10:00 – 10:40 a.m.	REFRESHMENT BREAK in Rushmore G – Sponsored by TransCanada		
10:40 a.m. – noon	Concurrent Session 2A in Alpine Room – Ecosystems (1.5 PDH) Moderator – Lacy Pomarleau, RESPEC	Concurrent Session 2P in Ponderosa Room – In-Situ Mining Issues (1.5 PDH) Moderator – Kelli McCormick, South Dakota School of Mines and Technology	Concurrent Session 2H in Rushmore H Room – Climate and Stormwater (1.5 PDH) Moderator – Bora Cetin, South Dakota School of Mines and Technology
10:40 – 11:00 a.m.	Stream health monitoring: Are we measuring what we think we are measuring? – Charles Jason Tinant, Delaine Peterson, Oglala Lakota College, and Delinda Simmons, Oglala Sioux Tribe Environmental Protection Program	Groundwater modeling of the hydraulic effects of the proposed Dewey Burdock uranium in-situ recovery project, Fall River and Custer County, South Dakota – Errol Lawrence, Hal Demuth, Petrotek Engineering Corporation, and John Mays, Powertech (USA), Inc.	An analysis of dryline structure and propagation influenced by the Black Hills – Erin Walter, Adam French, William Capehart, and Daren Clabo, South Dakota School of Mines and Technology
11:00 – 11:20 a.m.	Use of native algae to reduce nutrients in Lake Kampeska – Steven Quail, HDR Engineering, Inc.	Wastewater management at a proposed uranium in-situ recovery project – Jack Fritz, WWC Engineering, John Mays, Powertech (USA), Inc., and Hal Demuth, Petrotek Engineering Corporation	Long-term trends in mean annual streamflow in the United States for the period 1960 to 2012 – John Stamm, Mark Anderson, and Parker Norton, U.S. Geological Survey
11:20 – 11:40 a.m.	The influence of algae in aquatic ecosystems – Lisa Kunza, South Dakota School of Mines and Technology	In-situ recovery uranium mining restoration challenges – James Stone, South Dakota School of Mines and Technology, Thomas Borch, Amrita Bhattacharyya, Thomas Johnson, Elizabeth Ruedig, Colorado State University, and Ray Johnson, S.M. Stoller Corporation	Watershed fires and effects on storm water infrastructure – Richard Ommert and Dorothy Eisenbraun, RESPEC
11:40 a.m. – noon	Environmental performance monitoring of Superfund remedies in the Clark Fork River and Silver Bow Creek, Montana – Joe Naughton, RESPEC	In-situ recovery uranium mining restoration challenges: geochemical modeling of post-mining site conditions – Ryan Truax, James Stone, South Dakota School of Mines and Technology, Thomas Borch, Thomas Johnson, Colorado State University, and Ray Johnson, S.M. Stoller Corporation	Urban storm water master planning – a case study – Richard Ommert and Dorothy Eisenbraun, RESPEC

12:00 – 1:55 p.m.	<b>LUNCH in Rushmore F Room – with accompanying presentations (1.0 PDH)</b> <b>RESPEC: Cory Foreman</b> , Water Resources Manager <b>John T. Loucks Distinguished Lecture: Tom Loveland</b> (U.S. Geological Survey EROS Data Center) — <i>Landsat 8: A sharper eye in the sky</i>	
2:00 – 3:40 p.m.	<b>Concurrent Session 3A in Alpine Room – Anthropogenic Effects on Water Resources (1.5 PDH)</b> <b>Moderator – Greg Delzer</b> , U.S. Geological Survey	<b>Concurrent Session 3P in Ponderosa Room – Groundwater (1.5 PDH)</b> <b>Moderator – Joanne Noyes</b> , South Dakota Department of Environment and Natural Resources
2:00 – 2:20 p.m.	<i>Estimating impacts of tile drainage on crop consumptive water use – Jeppe Kjaersgaard, Kul Khand, and Christopher Hay</i> , South Dakota State University	<i>Characterization of glacial aquifer properties using geophysical methods near Aberdeen, South Dakota – Karl Koth and David Bender</i> , U.S. Geological Survey
2:20 – 2:40 p.m.	<i>Denitrifying bioreactors for improved tile drainage water management in South Dakota – Cynthuja Partheeban, Jeppe Kjaersgaard, Christopher Hay, and Todd Trooien</i> , South Dakota State University	<i>Development of a new methodology to estimate base flow using multivariate analysis in the Northern Great Plains – Jennifer Bednar, Andrew Long, and Roy Sando</i> , U.S. Geological Survey
2:40 – 3:00 p.m.	<i>Williston Basin baseline water-quality assessment – Joel Galloway, Joshua Valder, Jill Frankforter, and Peter McMahon</i> , U.S. Geological Survey	<i>Groundwater quality in Precambrian crystalline aquifers of the central Black Hills – Arden Davis, Alvis Lisenbee, Maribeth Price, Gary Smith, Erik Walega, and Henok Tiruneh</i> , South Dakota School of Mines and Technology
3:00 – 3:20 p.m.	<i>Septic system and groundwater quality in a vulnerable mountainous terrain – J. Foster Sawyer and Arden Davis</i> , South Dakota School of Mines and Technology	<i>A regional Black Hills groundwater-flow model of the Madison and Minnelusa aquifers: progress report – Andrew Long</i> , U.S. Geological Survey, <b>William Eldridge</b> , South Dakota School of Mines and Technology, and <b>Joshua Valder</b> , U.S. Geological Survey
3:20 – 3:40 p.m.	<i>Belle Fourche Irrigation District Indian Creek siphon replacement – Stephen Bareis and Jared Oswald</i> , RESPEC	<i>Pleistocene water-table fluctuations and shifts in aquifer contributions in Wind Cave National Park, Black Hills, South Dakota, USA – James Paces</i> , U.S. Geological Survey, <b>Margaret Palmer</b> , and <b>Arthur Palmer</b> , State University of New York
3:40 – 4:10 p.m.	<b>REFRESHMENT BREAK in Rushmore G</b>	
4:10 – 5:30 p.m.	<b>Concurrent Session 4A in Alpine Room – Hydrologic Extremes (1.5 PDH)</b> <b>Moderator – Melissa Smith</b> , National Weather Service	<b>Concurrent Session 4P in Ponderosa Room – Hydrogeologic Characterization and Erosion (1.5 PDH)</b> <b>Moderator – J. Foster Sawyer</b> , South Dakota School of Mines and Technology
4:10 – 4:30 p.m.	<i>Flooding at Renwick Dam, Tongue River Watershed, North Dakota, 2013 – Dennis Reep</i> , HDR Engineering, Inc., and <b>James Fay</b> , North Dakota State Water Commission	<i>Permeability of the Inyan Kara Group in the southern Black Hills area – Perry Rahn</i> , South Dakota School of Mines and Technology
4:30 – 4:50 p.m.	<i>2013 Record snowfall and precipitation in western South Dakota – Laura Edwards, Dennis Today</i> , South Dakota State University, <b>Matthew Bunkers</b> , National Weather Service, and <b>John Abatzoglou</b> , University of Idaho	<i>Hydrogeologic characterization of the Bear Lodge Rare Earth Element Project, Wyoming – Aaron Payne, Errol Lawrence</i> , Petrotek Engineering Corporation, <b>Brant Dennis</b> , BD GeoEnvironmental Services, <b>Paul Bergstrom</b> , and <b>Kris Thompson</b> , Rare Element Resources, Inc.
4:50 – 5:10 p.m.	<i>The “Shutdown” blizzard and flooding of October 2013 in western South Dakota – Melissa Smith</i> , National Weather Service	<i>Shoreline erosion rates and processes along Lake Sharpe near Lower Brule, South Dakota – John Stamm</i> , U.S. Geological Survey, <b>Lillian Temple</b> , <b>Soonkie Nam</b> , and <b>Tim Lowman</b> , South Dakota School of Mines and Technology
5:10 – 5:30 p.m.	<i>Revisiting statistical aspects of the hydrometeorological hazards in Bangladesh – Imteaz Bhuiyan and Asma Chowdhury</i> , University of Regina, Saskatchewan, Canada	<i>Leaching characteristics of recycled concrete aggregate used as highway base – Bora Cetin</i> , South Dakota School of Mines and Technology
5:30 – 7:30 p.m.	<b>POSTER SESSION AND EVENING SOCIAL (with refreshments) in Rushmore G</b> <b>Moderator – Janet Carter</b> , U.S. Geological Survey	
	Comparing nutrient demands and metabolism in two lake outlet streams containing <i>Didymosphenia geminata</i> in Grand Teton National Park	<b>Jaime Haueter</b> and <b>Lisa Kunze</b> , South Dakota School of Mines and Technology
	Snow measurements in Rapid City, South Dakota using a Parsivel Instrument	<b>Jorel Torres</b> and <b>Donna Kliche</b> , South Dakota School of Mines and Technology
	Benthic macro-invertebrate diet selection in Rapid Creek, South Dakota	<b>Russell Marlow</b> and <b>Lisa Kunza</b> , South Dakota School of Mines and Technology

	Effects of <i>D. geminata</i> on growth rates and secondary production of benthic macroinvertebrates in Rapid Creek, SD.	<b>Julie McGeary</b> and <b>Lisa Kunza</b> , South Dakota School of Mines and Technology
	Calibration of AgriDrain control structure by using generalized “V” notch weir equation for flow measurement	<b>Cynthuja Partheeban</b> , <b>Govinda Karki</b> , <b>Kul Khand</b> , <b>Jeppe Kjaersgaard</b> , <b>Christopher Hay</b> , and <b>Todd Trooien</b> , South Dakota State University
	A state-wide groundwater recharge estimate for South Dakota and the Black Hills in Wyoming	<b>William Eldridge</b> , South Dakota School of Mines and Technology, <b>Andrew Long</b> , U.S. Geological Survey, and <b>Katherine Aurand</b> , Norwegian University of Science and Technology
	Verification of a heavy precipitation event using the SDSMT real-time WRF forecasting system	<b>Brianne Gerber</b> and <b>Bill Capehart</b> , South Dakota School of Mines and Technology
	Influences on groundwater quality in Precambrian crystalline aquifers of the central Black Hills	<b>Henok Tiruneh</b> , <b>Gary Smith</b> , <b>Erik Walega</b> , <b>Maribeth Price</b> , <b>Arden Davis</b> , and <b>Alvis L. Lisenbee</b> , South Dakota School of Mines and Technology
	Assessing groundwater availability of the Williston and Powder River structural basins, Northern Great Plains	<b>Jennifer Bednar</b> , South Dakota School of Mines and Technology and U.S. Geological Survey, <b>Andrew Long</b> , <b>Joanna Thamke</b> , <b>Kyle Davis</b> , <b>Katherine Aurand</b> , <b>Timothy Bartos</b> , <b>Gary LeCain</b> , <b>Derek Ryter</b> , and <b>Roy Sando</b> , U.S. Geological Survey
	Development of elevation derivative datasets from USGS high-resolution digital elevation data near Sioux Falls, South Dakota	<b>Curtis Price</b> , <b>Steve Shivers</b> , <b>Ryan Thompson</b> , U.S. Geological Survey, and <b>Kristin O'Connor</b> , South Dakota School of Mines and Technology
	Effect of climate variability on corn yield in eastern South Dakota	<b>Gibril Vandy</b> , <b>Dennis Today</b> , and <b>Jeppe Kjaersgaard</b> , South Dakota State University
	Sustainability assessment and design criteria for irrigation for Lesotho	<b>Angelinah Ntsieng Rasoeu</b> , <b>Jeppe Kjaersgaard</b> , <b>Tood Trooien</b> , and <b>Chris Hay</b> , South Dakota State University

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**WEDNESDAY, APRIL 9, 2014**

**SESSION 1**

**8:00 – 10:00 A.M.**

**2014 THEME: INTEGRATED WATER-RESOURCES MANAGEMENT  
(ALPINE/PONDEROSA ROOMS)**

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## **MONGOLIA: INTEGRATING CULTURES, PEOPLE, AND RESEARCH**

**Scott J. Kenner**

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57701, email: *Scott.Kenner@sdsmt.edu*

This talk will highlight activities Dr. Scott Kenner experienced on his Fulbright Scholarship to Mongolia. Over his ten month stay in Mongolia he spent half his time working in Ulanbaatar the capitol city and half his time in Erdenet, a major mining community. His experiences include Khuvsgul Lake, in the north, to Shambhala Monastery in the southern Gobi Desert. Mongolia was ruled by the Soviet Union until 1990 when it separated and established a democratic Mongolia. The historical herder lifestyle is becoming dominated by urbanization of Ulanbaatar and significant growth in development of natural resources especially cooper, coal, gold and uranium. Dr. Kenner taught courses and collaborated on research with faculty and students at the Mongolia University of Science and Technology, National University of Mongolia and Erdenet Institute of Technology. Working with Soninkhishig Nergue, physical habitat analysis along with statistical analysis of daily flow records was done to develop environmental low flows on the Orkhon River to support analysis of proposed reservoirs. Additionally water balance analysis was done for the Erdenet Cooper Mine in collaboration with Kh Oyuntungalag from Erdenet Institute of Technology.

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**WEDNESDAY, APRIL 9, 2014**  
**SESSION 2A**  
**10:40 A.M. – 12:00 P.M.**

**ECOSYSTEMS**  
**(ALPINE ROOM)**

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# **STREAM HEALTH MONITORING: ARE WE MEASURING WHAT WE THINK WE ARE MEASURING?**

**Charles Jason Tinant**

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**Delaine Peterson**

BS Earth Science, Oglala Lakota College

**Delinda Simmons**

Data Manager, Oglala Sioux Tribe Environmental Protection Program

Water is an essential resource, yet freshwater ecosystems are directly threatened by human activities. There is a need to improve water quality monitoring beyond measuring water chemistry in order to evaluate trends in ecosystem structure. Stream health metrics were calculated from macroinvertebrate samples collected 1993 – 1996 and 2008 – 2011 for Pine Ridge Reservation streams. We evaluated these data using two-way MANOVA to determine if significant differences exist across ecoregions, land use intensities and/or time. Three levels of land use intensity were distinguished by the life history of the dominant taxon in each sample. Our results indicate statistically significant differences between ecoregions, land use intensity, and a land use x ecoregion interaction. ANOVA and Tukey's Honestly Significant Difference tests were conducted as post-hoc analyses. The results indicate: 1) %EPT, %Dipteran and Non-Insect, and %Collector Gatherer metrics significantly differ by ecoregion, 2) EPT Index, %EPT, Family Biotic Index (FBI), Dipteran and Non-Insect, and Collector Gatherer metrics significantly differ by land use, 3) taxa richness and % dominance metrics could not detect land use changes, 4) FBI and %Collector Gather values have significantly increased over time, and 5) the Badlands ecoregion has significantly higher %EPT and Collector Gather values at moderate and high land use intensities. Based on our results we conclude: 1) biotic stream health assessment should continue at the ecoregion level, 2) several stream health metrics selected for biological assessment are able to detect water quality responses to changes in land use, however taxa richness and % dominance metrics should be replaced with alternative metrics, 3) the PRR macroinvertebrate community has become more tolerant and has lost trophic diversity over time, and 4) the assimilative capacity of Badlands streams is greater than for other ecoregions on the PRR.

# USE OF NATIVE ALGAE TO REDUCE NUTRIENTS IN LAKE KAMPESKA

## **Steven J. Quail, PE**

Senior Project Manager, HDR Engineering, Inc., 6300 Old Village Place, Suite 100, Sioux Falls, SD 57108, email: *Steven.quail@hdrinc.com*

Lake Kampeska is faced with exceedingly high nutrient (phosphorus and nitrogen) levels, leading to chronic algal blooms and diminished water quality. As a result, the City of Watertown, South Dakota, along with its partners, Upper Big Sioux River Watershed Project and Lake Kampeska Water Project District, retained HDR to design an innovative demonstration project to reduce phosphorus concentrations from Lake Kampeska using algae. Reducing nutrients from the lake water decreases the potential for algal blooms and enhances the lake's water quality for recreational uses, fish habitat and wildlife.

This unique facility is designed to operate year round, including winter operations when days are short and the lake is iced over. Traditional systems use outdoor tanks and sunlight to grow algae for nutrient removal. However, these systems cannot be operated in northern climates during the winter because of freezing problems. Repurposing the existing decommissioned Water Treatment Plant was an economical way to allow winter operations.

Lake water is pumped to the plant's clearwell, where red and blue LED lights were mounted on the clearwell ceiling to provide the appropriate light spectrum and intensity to grow algae. Using only native algae, the phosphorus and nitrogen are consumed from the lake water. The algae are harvested using a bag filter prior to returning the water to the lake.

HDR's design improves upon the natural process by enhancing the conditions to grow native algae without the use of chemicals, using only light and air to remove excess nutrients from the lake water. The sole byproduct of the process is algae, which may be used for other beneficial uses such as biofuel production, soil amendments or even pharmaceutical products. Data obtained from this project may be used in future restoration projects at Lake Kampeska or other similar lakes.

# THE INFLUENCE OF ALGAE IN AQUATIC ECOSYSTEMS

**Lisa A. Kunza**

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Humans have greatly altered aquatic ecosystems through direct and indirect additions of nitrogen and phosphorus. This dramatic shift in biogeochemistry has affected aquatic ecosystem structure and function across the globe. Increasing occurrence of harmful algal blooms in lakes, coastal waters, and oceans, may partly be explained by the alteration of nutrient loading to these ecosystems. Whether an ecosystem is nutrient rich or poor, algae are at the base of aquatic food webs. I will describe two research projects that link biogeochemistry with algal assemblages and implications for food webs. First, I will explain the role of nitrogen fixation in low nutrient streams. Without nitrogen fixers, few organisms could survive in low nutrient ecosystems. Second, I will briefly explain a project that will examine how a particular nuisance alga, *Didymosphenia geminata*, may alter stream ecosystem structure and function.

# **ENVIRONMENTAL PERFORMANCE MONITORING OF SUPERFUND REMEDIES IN THE CLARK FORK RIVER AND SILVER BOW CREEK, MONTANA**

**Joe Naughton**

Fisheries Biologist, RESPEC, 1535 Liberty Lane, Suite 110D, Missoula, MT 59808, email:  
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Uncontrolled disposal of copper mining and smelting wastes from the Butte Hill mining district resulted in extirpation of fishes from Silver Bow Creek throughout the twentieth century and repeated fish kills in the Clark Fork River. The uppermost 120-mile reach of the Clark Fork River and Silver Bow Creek (approximately 30 miles) are now designated as Superfund Operable Units. Superfund remediation, implemented by the Montana Department of Environmental Quality, is near completion in Silver Bow Creek but just beginning in the Clark Fork River. RESPEC staff have performed comprehensive environmental monitoring of both Operable Units since 2010 to evaluate the environmental response of multiple media (surface water, groundwater, vadose zone water, instream sediment, macroinvertebrates, periphyton, fisheries, geomorphology, and floodplain vegetation) to the remedy. In addition to metal contamination, both Operable Units are influenced by dewatering and nutrient enrichment that results in elevated summer water temperatures and nighttime hypoxia in Silver Bow Creek. Despite these problems, ecological response to the remedy in Silver Bow Creek has been dramatic. For example, indigenous westslope cutthroat trout *Oncorhynchus clarkii lewisi* have recolonized Silver Bow Creek. Generally, environmental damages to the Clark Fork River were less severe and, therefore, ecological responses to the remedy may be subtle. Identifying subtle environmental responses will likely require detailed data. Although the data collected in these monitoring programs are primarily intended to evaluate remedial performance goals, these data will provide an extensive resource from which to design and calibrate ecological models to inform future large-scale river restoration.

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**WEDNESDAY, APRIL 9, 2014**  
**SESSION 2P**  
**10:40 A.M. – 12:00 P.M.**

**IN-SITU MINING ISSUES**  
**(PONDEROSA ROOM)**

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# **GROUNDWATER MODELING OF THE HYDRAULIC EFFECTS OF THE PROPOSED DEWEY BURDOCK URANIUM INSITU RECOVERY PROJECT, FALL RIVER AND CUSTER COUNTY, SOUTH DAKOTA**

## **Errol P. Lawrence**

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A numerical groundwater flow model was developed to support Powertech USA in permitting, planning and operation of the Dewey-Burdock Uranium Insitu Recovery (ISR) project in Fall River and Custer Counties, South Dakota. The target ore zones are within the Inyan Kara Group along the southwest flank of the Black Hills. The model was developed and calibrated using site-specific geologic and hydrologic data. Development of the numerical model improved understanding of the regional and local flow patterns, recharge and discharge boundaries, and overall water budget (available and sustainable resources) of the Fall River and Chilson aquifers (sub-systems of the Inyan Kara). Model simulations were used to evaluate potential hydraulic impacts (e.g. drawdown and changes to artesian conditions) from ISR production and restoration operations on both the local and regional scale.

Fourteen wellfields were simulated for a period of 8.5 years through production and aquifer restoration operations. Model simulations were run using anticipated production rates with variable bleed rates (net extraction) of 0.5 to 1.0 percent. Multiple aquifer restoration methods were also simulated. Maximum net extraction was simulated during periods with concurrent production and aquifer restoration with rates up to 147 gpm.

Results of the simulations indicate that:

- production at the projected rates of up to 8,000 gpm (40 gpm per well pattern) with a 0.5 to 1.0 percent net extraction for a period of 8.5 years did not result in dewatering of the aquifers;
- maximum drawdown outside of the Project Area was simulated as less than 12 feet throughout the entire life cycle of the ISR project; and
- water-levels recover to near pre-operational elevations within 1 year after ISR operations cease.

The groundwater model simulation results support the viability of Uranium ISR mining of the Inyan Kara.



# **WASTEWATER MANAGEMENT AT A PROPOSED URANIUM *IN-SITU* RECOVERY PROJECT**

**Jack W. Fritz**

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**Hal Demuth, P.G.**

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Uranium *in-situ* recovery (ISR) projects require wastewater management systems to dispose of the excess water that results from uranium recovery and groundwater restoration. During uranium recovery, groundwater fortified with oxygen and carbon dioxide is recirculated through well fields to dissolve and recover uranium. Following uranium recovery, treated water or water from an aquifer outside of the production zone is circulated through each well field to restore groundwater quality. Slightly more water is withdrawn than injected (about 1 percent) during uranium recovery and groundwater restoration in order to maintain an inward hydraulic gradient into each well field. The excess water, known as bleed, requires disposal in an appropriately permitted wastewater management system.

Two wastewater management systems are being permitted at the Dewey-Burdock Project in Custer and Fall River counties. The preferred method is treatment to remove uranium and radionuclides followed by injection in disposal wells completed in the Minnelusa or Deadwood formations. The alternate method is land application, which will be used only in the event that insufficient capacity is available in disposal wells.

The land application system designed for the Dewey-Burdock Project is the primary focus of this oral presentation. It would consist of center pivots to dispose treated wastewater during the irrigation season and lined ponds to provide storage during the rest of the year. The land application system is designed to protect surface water and groundwater and includes provisions for operational adjustments based on extensive monitoring.

Having adequate wastewater management capacity is critical for timely groundwater restoration and maintenance of sufficient bleed for hydraulic well field control. Permitting two wastewater management systems, as opposed to a single option employed at most ISR facilities, helps ensure that adequate capacity will be available for these purposes.

# IN-SITU RECOVERY URANIUM MINING RESTORATION CHALLENGES

## **James Stone**

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## **Thomas Borch**

Associate Professor, Department of Soil and Crop Sciences and Department of Chemistry, Colorado State University

## **Amrita Bhattacharyya**

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## **Thomas Johnson**

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In-situ recovery (ISR) uranium mine restoration is generally based upon a return of the site to baseline conditions. Little or no scientific information is used to justify utilizing baseline conditions for regulatory compliance and the constituents monitored for compliance have not been evaluated to ensure they are proper indicators of restoration. We examine the pre-existing aquifer parameters, thereby allowing a complete scientific evaluation of the changes that occur during mining, so that specific recommendations can be made on how best to accomplish restoration of those constituents that most impact human and environmental health. The three overarching research objectives of this study are a) health effect determination to perform an assessment of constituent toxicity, pathways to humans, and health risks as well as an evaluation of the health impact of different remediation endpoints including a water cost analysis and finally recommendations for regulatory action, b) geochemical characterization of baseline conditions and comparison to a mined site of redox reactive minerals and important sorbents, and c) hydrological evaluation and modeling analyses to integrate the hydrologic and geochemical data and associated interpretations into a predictive mathematical model analysis of the baseline and post reclamation conditions. In this presentation, preliminary geochemical analysis results from an unmined site will be compared to a mined site to assist with the evaluation of mining impacts and the potential for natural attenuation of contaminants. This work will advance understanding of the processes associated with the reductive sequestration of U from groundwater and will provide regulators with sound scientific evidence for optimizing remediation goals.

# **IN-SITU RECOVERY URANIUM MINING RESTORATION CHALLENGES: GEOCHEMICAL MODELING OF POST-MINING SITE CONDITIONS**

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In-situ recovery (ISR) uranium mine restoration is generally based upon a return of the site to pre-mining baseline conditions. Uranium ISR sites typically exhibit varying degrees of natural attenuation potential that may influence the degree of restoration required. Surface complexation modeling provides useful insight into the geochemical restoration potential of a mined aquifer, providing stakeholders with a better understanding of potential restoration requirements and challenges for specific pre- and post-mining geochemical conditions. This presentation will summarize findings from our 1-D uranium transport surface complexation modelling efforts for an existing ISR mine. Batch adsorption isotherm experiments were conducted using post-mining/pre-reclamation, and post-mining/post-reclamation soil core samples, site upgradient groundwater water, and completed using varying pH and uranium concentrations. Isotherm filtrates were analyzed by ICP-OES, and results used to determine soil attenuation capacity using a combination of PHREEQC for geochemical and transport calculations, and PEST for parameter fitting. A general composite, site-specific mineral assemblage approach was used the surface complexation estimates. Forward model runs were completed to predict the transport of uranium plumes during various mine restoration geochemical conditions.

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**WEDNESDAY, APRIL 9, 2014**  
**SESSION 2H**  
**10:40 A.M. – 12:00 P.M.**

**CLIMATE AND STORMWATER**  
**(RUSHMORE H ROOM)**

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# **AN ANALYSIS OF DRYLINE STRUCTURE AND PROPAGATION INFLUENCED BY THE BLACK HILLS**

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Drylines are surface boundaries separating moist, maritime tropical air from dry, continental air. They are associated with a gradient in low-level moisture that is influenced by changes in soil moisture. Since fluctuations in surface hydrology affect dryline evolution, monitoring surface hydraulics can aid in forecasting dryline activity. Drylines are favorable locations thunderstorm initiation, which makes understanding them an important factor in forecasting thunderstorms and their associated hazards.

The objective of this project is to determine how dryline evolution is impacted by the Black Hills. The Hills form an isolated, elevated topographic feature in the Northern Plains roughly 100 miles east of the Rocky Mountains. They also represent a distinct change in landuse from the surrounding grassland prairie as they are primarily composed of a ponderosa pine forest. Initial observational results revealed that The Hills often appear to locally slow the eastward progression of the dryline. Since past studies have shown that terrain slope and soil moisture can have significant effects on the dryline morphology, we are interested in determining which of these factors is playing a bigger role in governing dryline evolution over the Black Hills.

To address this question, four Weather Research and Forecasting (WRF) simulations have been run for the 2010 dryline season. The first was configured to approximate the observed dryline behavior. The following tests alter the landuse (replacing the ponderosa pine forest over the hills with grassland), terrain shape (flattening the Black Hills), and the combination of both of these effects. This series of test isolates the effects of surface moisture (associated with landuse differences) from the effects of topographically forced flows near the Hills. This presentation will use output from these simulations to discuss the processes responsible for dryline propagation over the Black Hills.

# **LONG-TERM TRENDS IN MEAN ANNUAL STREAMFLOW IN THE UNITED STATES FOR THE PERIOD 1960 TO 2012**

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Long-term trends in mean annual streamflow were examined in the United States for evidence of climate change. Streamflow serves as a useful integrator of many climate factors, such as precipitation, evapotranspiration, temperature and other hydrologic processes. The U.S. Geological Survey network of gaging stations with continuous record for the period 1960 through 2012 were considered and analyzed using the Kendall Tau statistical method looking for monotonic trends at a p-value greater than or equal to 0.1. Of the stations with 53 years of continuous record, 507 had upward trends while 276 stations had downward trends. Distinct geographic patterns of upward and downward trends emerged. Upward trends predominate in a band of stations extending from the eastern Dakotas through the Midwest to the New England states. Downward trends predominate in the southeastern United States and the Rocky Mountains of Wyoming, Montana and Idaho. Of those stations with upward trends, 56 stations had an increase in the annual mean that more than doubled from 1960 to 2012. The James River in South Dakota and the Red River of the North in North Dakota stand out for the magnitude of increase and the volume of water the increase represents. Of those stations with downward trends, 35 stations had a decrease that was more than half of the annual mean from 1960 to 2012. This presentation will provide details of these trends, the volumes of water represented, the associated precipitation trends and some evidence of land use change.

# **WATERSHED FIRES AND EFFECTS ON STORM WATER INFRASTRUCTURE**

## **Richard Ommert**

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## **Dorothy Eisenbraun**

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The development of pre-fire and post-fire hydrology along with design of needed infrastructure improvements to accommodate higher peak flows and substantial debris volumes will be overviewed. Prior to the 2012 Waldo Canyon Forest Fire runoff from areas upstream of US Highway (US 24) was safely conveyed beneath the highway. The fire substantially altered the watershed hydrology causing runoff rates and debris flow volumes to increase dramatically. The effects of the fire and impacts to storm water infrastructure will be presented as a case study.

This change to the watershed hydrology resulted in several highway overtopping events causing extensive roadway damage, frequent road closures, and travelling public safety concerns. After the damaging effects of the August 2103 flood event, an emergency response project was initiated. The Colorado Department of Transportation requested RESPEC to assist with mitigating the adverse impacts. RESPEC was tasked with the design of: a larger US 24 structure to eliminate roadway overtopping, grade control structures on Fountain Creek to improve channel instability, and a structural fence/debris basin to capture debris reducing impacts to downstream areas including the town of Manitou Springs.

## **URBAN STORM WATER MASTER PLANNING – A CASE STUDY**

### **Richard Ommert**

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For an effective urban storm water master planning effort the primary technical focus and first step undertaken is completion of hydrologic & hydraulic modeling of the watershed. This foundation will help to evaluate and establish the need for channel, storm sewer, detention, and permanent water quality facility improvements. A framework will be presented that identifies storm water alternatives to be considered, the conceptual design for such, and cost estimate preparation. The master planning framework can be considered for adoption by local governments to develop their long-term urban storm water management plans for their urban or urbanizing areas. A case study will be used to describe an effective approach to watershed master planning.



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**WEDNESDAY, APRIL 9, 2014**

**LUNCHEON**

**12:00– 1:55 P.M.**

**JOHN T. LOUCKS DISTINGUISHED LECTURE:**

**DR. TOM LOVELAND**

**“LANDSAT 8: A SHARPER EYE IN THE SKY”**

**(RUSHMORE F ROOM)**

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**WEDNESDAY, APRIL 9, 2014**

**SESSION 3A**

**2:00 – 3:40 P.M.**

**ANTHROPOGENIC EFFECTS ON WATER RESOURCES  
(ALPINE ROOM)**

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# **ESTIMATING IMPACTS OF TILE DRAINAGE ON CROP CONSUMPTIVE WATER USE**

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Subsurface (tile) drainage on agricultural land with poor natural drainage allows timelier field operation and contributes to improved crop yields. Considerable uncertainty exists regarding the impact of the tiles in individual fields on the hydrology at the watershed scale. The installation of tile drainage systems have been implicated in changing water yield from farms in a manner that can result in increased incidence of flooding and more erosive rivers, potentially linking basin-scale water quality problems to farm-scale changes in the water budget. Uncertainty also exists regarding the impacts of tile drainage on crop consumptive water use. Eastern North and South Dakota lies in a transitional zone between the subhumid Midwest and the semiarid Great Plains and is susceptible to both excess and a shortage of soil moisture. While draining excess soil moisture early in the growing season may be a sound management decision to allow for timely field operations, this export of water may result in water short conditions later in the growing season during sustained periods without rainfall. Knowledge of the impact of tile drainage on crop water use and yield is important for on-farm water and crop management and drives decisions regarding tile drainage system design and drainage water management. The objectives of this study are to estimate and compare the crop consumptive water use from fields with and without tile drainage. METRIC (Mapping Evapotranspiration at high Resolution with Internalized Calibration) utilizes satellite imagery to estimate water consumptive use from bare soil and vegetation on a field-by-field basis (30 m). This is advantageous because of the ability to compare crop consumptive use from fields with and without tile drainage. This research examines the utility of using METRIC to estimate crop water use under different tile drainage scenarios and compares the ET estimates produced by METRIC to ground-based flux measurements.

# DENITRIFYING BIOREACTORS FOR IMPROVED TILE DRAINAGE WATER MANAGEMENT IN SOUTH DAKOTA

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Export of nitrate-nitrogen from agricultural fields through subsurface (tile) drainage systems have been identified as a major contributor to eutrophication and hypoxia in natural aquatic ecosystems, especially estuaries. Low cost, simple technologies are needed to remove the nitrate-nitrogen before entering the surface waters. Woodchip denitrifying bioreactors, where water containing nitrate-nitrogen is passed through a carbon medium (such as woodchips) and converted to inert nitrogen gas via denitrification has showed high nitrate removal rates. The objective of this study is to analyze the nitrate removal performance of three bioreactors we have installed in South Dakota during 2012 and 2013. Since the installation, we have collected water samples twice per week upstream and downstream of the reactors. We analyzed the samples for nitrate-nitrogen concentration. The concentration-based average nitrate reduction at our Baltic bioreactor was 81% with a minimum load reduction of 11% and a maximum load reduction of 100%. At our Montrose bioreactor, average nitrate load reduction was 51% with a minimum load reduction of 11% and a maximum load reduction of 99%. The nitrate removal performances from the bioreactors are analyzed along with factors affecting the performance including water temperature, bioreactor flow rate, retention time, and nitrate concentration in the inlet water using multiple regression analysis using SAS. A supporting bench-scale experiment has been completed to calibrate the Agridrain water level control structure using a generalized V notch equation relationship producing the equation which was used to convert the depth of water in the control structures into flow rate. The average mass removal rate from the Montrose bioreactor was estimated as 1.4 g N/m<sup>3</sup>/day. A preliminary economic analysis showed that for the Baltic site the bioreactor costs \$24 per year per ha of treatment area assuming a lifetime of the woodchips of 20 years. We will compare these costs with other nitrate reduction strategies in terms of cost effectiveness.

# **WILLISTON BASIN BASELINE WATER-QUALITY ASSESSMENT**

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The U.S. Geological Survey initiated a study in 2013 to characterize baseline water-quality conditions in the Upper Fort Union aquifer within a portion of the Williston Basin located in Montana and North Dakota. This study was intended to assess the recent energy development within the Williston Basin and its effect on water-quality conditions of shallow groundwater aquifers. In an effort to characterize the baseline water-quality conditions, the Upper Fort Union aquifer was selected based on water use and the aquifers proximity to the land surface and spatial extent. Within the Upper Fort Union, a spatially distributed randomized grid-based method was used to select 30 domestic wells to sample for an extensive suite of water-quality constituents. In addition to field measurements (that is, temperature, pH, dissolved oxygen, specific conductance, turbidity, sulfide, and alkalinity) samples from each well were analyzed for major ions, trace metals, nutrients, volatile organic compounds, methane and ethane, hydrogen and carbon isotopes of methane, and hydrocarbon gas composition. A subset of 10 wells also were sampled for multiple isotopic and groundwater-age tracers to improve the understanding of recharge and groundwater movement in the aquifer. Results of the age dates, on the basis of carbon-14 and helium-4 data, indicate that most of the sampled water was recharged several thousand years ago, which may imply, in part, low recharge rates and slow groundwater velocities in the aquifer. The implications of slow groundwater velocities in the aquifer imply that the occurrence of contaminants associated with oil and gas extraction may go undetected if the sampled well is not located in close proximity to the source. Results of this study highlight the need to better understand the recharge and groundwater movement in areas of current and potential energy development with respect to water availability and establishing an effective monitoring program to characterize the groundwater quality conditions.

# SEPTIC SYSTEMS AND GROUNDWATER QUALITY IN A VULNERABLE MOUNTAINOUS TERRAIN

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On-going installation of on-site wastewater treatment systems (septic systems) in mountainous terrains such as the Black Hills of western South Dakota and many other areas raises significant questions and poses unique challenges with respect to protection of vulnerable groundwater recharge areas. In the Black Hills, overlapping and interconnected aquifer recharge areas for karst carbonate aquifers, fractured sedimentary and crystalline bedrock reservoirs, and shallow alluvial aquifers are further complicated by groundwater and surface-water interaction within all of these hydrogeologic settings. High velocity groundwater flow within portions of the Madison aquifer, western South Dakota's most valuable groundwater resource, as well as thin soil cover in many areas, heightens the need for appropriate protection measures.

Accurate characterization of the effects on groundwater and surface-water quality from effluent discharged by thousands of septic systems in these hydrogeologic settings is difficult to achieve, and city and county governments frequently are forced to balance the rights of private property owners with implementation of aquifer protection measures that affect property values, development potential, tax revenues, and privacy with respect to government regulations. However, undesirable societal effects from increased regulations must be weighed against potential economic losses ranging into the tens or hundreds of millions of dollars that could result from damage or partial loss of the Madison and other aquifers. Intangible benefits of clean water for drinking, recreation, and overall quality of life are more difficult to quantify economically, but are equally important.

## **BELLE FOURCHE IRRIGATION DISTRICT INDIAN CREEK SIPHON REPLACEMENT**

### **Stephen W. Bareis**

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This paper presents a synopsis of construction activities related to removing and replacing a 1,300-foot siphon on the Belle Fourche Irrigation District (BFID). The existing 96-inch-diameter, steel siphon pipe is a key component of the BFID's delivery system and transports flows of up to 450 cubic feet per second (cfs) in the North Canal across Indian Creek. The North Canal conveys water from the Belle Fourche Reservoir along the northern perimeter of the BFID to the project end east of Newell, South Dakota. The existing raised siphon, on concrete supports, is deteriorated and leaks through several expansion joints. Additionally, the valley floods periodically, which cause debris to build up against the pipe. This buildup creates lateral loads and threatens to displace the pipe. For these reasons, designs were developed for concrete pipe to be installed beneath the valley floor.

Investigations and designs were completed in 2012. The siphon is owned by the federal government under the management of the U.S. Bureau of Reclamation, and is operated by the BFID. Construction began in the fall of 2013 and will be complete in April 2014. The principle components of work include removing existing pipe; diverting Indian Creek; dewatering and excavating for pipe installation; installing 1,300 feet of gasketed, reinforced concrete pressure pipe; and bedding/backfilling the pipe sections. Winter construction conditions, tie-ins to existing headwalls, and diverting the stream during construction were challenging during some of the project phases. The testing procedures employed and the blow-off assemblies installed to allow access and partial draining of the siphon each year are of special interest.

The BFID is scheduled to complete a similar project in the fall of 2014 that will replace a 600-foot, above-grade siphon across Horse Creek with buried concrete pipe.

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**WEDNESDAY, APRIL 9, 2014**  
**SESSION 3P**  
**2:00 – 3:20 P.M.**

**GROUNDWATER**  
**(PONDEROSA ROOM)**

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# **CHARACTERIZATION OF GLACIAL AQUIFER PROPERTIES USING GEOPHYSICAL METHODS NEAR ABERDEEN, SOUTH DAKOTA**

## **Karl Koth**

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An integrated, non-invasive geophysical approach was developed to characterize glacial aquifer properties north of Aberdeen, South Dakota. Aquifers contained within buried glacial sand and gravel channels are not identifiable from surface geology because they commonly are covered by glacial till. Density differences, however, that result from spatial variations of glacial materials cause gravity anomalies over buried channels that can be measured to create gravity anomaly maps. Two gravity anomaly surveys were performed in the Aberdeen area. The first 7.7-mile line survey consisted of 18 gravity measurements along a county road (130th Street), which coincided closely with an existing cross section created from well logs. The second survey covered an area of approximately 6 square miles with measurements spaced between 1,000 and 2,500 feet along section lines near Ordway Dam and Elm Creek which is north of Aberdeen. Analysis of the gravity data indicates lower density materials (negative gravity anomalies) where glacial aquifers are noted in well logs.

Horizontal-to-vertical spectral ratio (HVSr) seismic surveys also will be performed over the same study area in addition to the gravity anomaly surveys. The HVSr method uses a single, broad-band, three-component seismometer to record ambient seismic noise. The ratio of the horizontal-to-vertical frequency spectrum components can be interpreted to estimate sediment thickness overlying bedrock. These complementary data will provide a basis for determining areas of high transmissivity (that is, the presence and thickness of buried glacial channels), which are more favorable locations for future groundwater resource development.

# **DEVELOPMENT OF A NEW METHODOLOGY TO ESTIMATE BASE FLOW USING MULTIVARIATE ANALYSIS IN THE NORTHERN GREAT PLAINS**

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Base-flow estimation is commonly performed by using graphical or chemical hydrograph separation methods that have many limitations due to the spatial and temporal availability of data. Current graphical separation methods are limited in that they rely solely on streamflow records, whereas chemical methods are expensive and involve intense data collection. Graphical hydrograph separation methods are applicable to perennial and gaining streams but result in large uncertainty when applied to ephemeral or losing streams that are typical of dry climates.

A new methodology planned for development will consist of multivariate analysis to determine which spatial and temporal variables are controlling factors for base flow. Data used in the development of this methodology will include geologic, hydrologic, climatic, land surface, and remotely sensed data that are widely available to the public. Factors considered will include geologic media, flow-duration curves, temporal variability of streamflow, stream type, precipitation, drought-severity index, land-surface slope, and vegetation. This research will examine differences in variables controlling base flow between dry and humid climates, perennial and ephemeral streams, and gaining and losing stream reaches. Although the accuracy of each variable will vary, the use of multivariate analyses will help compensate for those with low accuracy.

Base-flow estimates were previously calculated for all streams with available streamflow data located in the Williston and Powder River structural basins using the U.S. Geological Survey hydrograph separation software, PART; these streams, in addition to streams not previously analyzed, will be evaluated by using the methodology that are being developed. The study area for this research will include most of Montana, North Dakota, South Dakota, Wyoming, and parts of Nebraska.

# **GROUNDWATER QUALITY IN PRECAMBRIAN CRYSTALLINE AQUIFERS OF THE CENTRAL BLACK HILLS**

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This work examined the water quality of Precambrian crystalline aquifers in the central Black Hills near Hill City and Keystone. Ninety private wells were sampled in the spring and fall of 2013. Analyses were compiled along with information from available records of public water systems. Samples taken in 2013 were analyzed for arsenic, calcium, magnesium, hardness, iron, sulfate, nitrate, and bacterial data. Results show that 30% of private well samples exceeded 10 µg/L for arsenic concentration. The arsenic is most likely from weathering of arsenopyrite in Precambrian metagraywacke and within mineralized zones. Almost half of the private well samples showed hardness above 170 mg/L, expressed as CaCO<sub>3</sub>. About 35% of the private well samples exceeded the recommended concentration of 0.3 mg/L for iron. Two private well samples had sulfate concentrations greater than 250 mg/L. Four of the private well samples exceeded 10 mg/L for nitrate. Almost half of the private well samples showed total coliform bacteria. In addition, thirteen of these same wells showed fecal coliform bacteria.

# **A REGIONAL BLACK HILLS GROUNDWATER-FLOW MODEL OF THE MADISON AND MINNELUSA AQUIFERS: PROGRESS REPORT**

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The Madison and Minnelusa aquifers are critically important water resources in the Northern Great Plains and, in particular, the Black Hills area. These aquifers can substantially affect surface-water systems and provide the most important source of groundwater in this area for municipal, domestic, agricultural, and industrial use. Rapidly increasing demand from these aquifers may affect long-term groundwater and surface-water availability. Therefore, the U.S. Geological Survey is constructing a regional numerical groundwater-flow model of the Madison and Minnelusa aquifers in cooperation with the National Park Service, the Black Hills National Forest, and the West Dakota Water Development District, with a primary focus on the Black Hills area. The modeled area includes much of western South Dakota and northeastern Wyoming. The areal extents of previous groundwater-flow models of these aquifers are limited to the Rapid City area and northern Black Hills. Future modeling needs are likely to include simulations of other areas of the Black Hills as well as updated simulations in previously modeled areas. These needs could be met with a regional Black Hills groundwater-flow model, which has several additional advantages over separate local models. First, developing this single regional model is more cost effective than developing multiple smaller models. Second, simulation of site-specific areas is most accurate within a regional flow model because artificial model boundaries are not necessary. Third, Black Hills artesian springs are critical water sources that capture regional groundwater and thus are best simulated with a regional model. Fourth, the regional model grid can be refined for high-resolution simulations in any area of special interest or to answer specific hydrologic questions, such as local-scale effects of pumping. Fifth, the regional model is being constructed in the new MODFLOW-USG software that can simulate pipe flow in karst conduits. The regional model's three-dimensional framework and potentiometric surfaces are now constructed. Recharge from precipitation was estimated by using a soil-water-balance model and ranges from <0.1 to 10 inches per year. Total groundwater recharge from sinking streams was estimated to be about 66 and 13 cubic feet per second to the Madison and Minnelusa aquifers, respectively.

# PLEISTOCENE WATER-TABLE FLUCTUATIONS AND SHIFTS IN AQUIFER CONTRIBUTIONS IN WIND CAVE NATIONAL PARK, BLACK HILLS, SOUTH DAKOTA, USA

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Wind Cave records a long history of karst formation including Pleistocene calcite deposits that are mostly restricted to the lower levels of the cave. Deposits form coatings on open passage and precipitated under phreatic conditions, although textures and mineralogy also indicate periods of vadose deposition. Coating thickness ranges from a few mm to 1–2 cm and generally decreases with height above the modern water table. These deposits offer an opportunity to understand the history of Pleistocene water table fluctuations as well as changing water sources in the Madison aquifer.

We collected speleothems along an 85 m vertical transect from the top of Boxwork Chimney to Calcite Lake (CL), which represents the modern regional water table. Calcite rafts and outermost surfaces of laminated crusts represent the latest phreatic mineral precipitation at a given site. Basal layers were deposited on altered substrates and represent initial flooding with calcite-saturated water. Most  $^{230}\text{Th}/\text{U}$  ages range from about 280–70 ka and vary systematically with height above CL. The resulting paleohydrograph suggests a long period of non-deposition prior to 300 ka followed by a rapid rise of groundwater to its maximum level of ~80 m above CL at ~220 ka. By 70 ka, water levels dropped to ~20 m (long-term average rate of ~0.4 m/ka). Growth rates for 14 subsamples from a single 13-mm-thick laminated crust at ~42 m above CL imply that growth was more rapid during glacial or stadial periods between 276–261 ka, 233–222 ka, and 192–171 ka, with no deposition between 170 and the outermost layer dated at 126 ka. Young phreatic deposits are scarce, although a few rafts within ~17 m of the water table have ages <12 ka.

Isotopes of C, O, Sr, and U were used to evaluate how groundwater sources varied over time. Deposits <12 ka have compositions consistent with deposition from groundwater similar to modern CL that reflects local recharge and relatively short flowpaths. Older deposits precipitated from groundwater with substantially lighter  $\delta^{18}\text{O}$  and higher  $^{234}\text{U}/^{238}\text{U}$  AR values implying recharge during colder climates and longer/deeper flowpaths. Elevated  $\delta^{87}\text{Sr}$  in some samples indicates a greater component of water from the Precambrian core of the Black Hills. Changes in groundwater recharge or aquifer transmissivity are likely drivers of the observed variations.

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**WEDNESDAY, APRIL 9, 2014**

**SESSION 4A**

**4:10 – 5:30 P.M.**

**HYDROLOGIC EXTREMES  
(ALPINE ROOM)**

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# **FLOODING AT RENWICK DAM, TONGUE RIVER WATERSHED, NORTH DAKOTA, 2013**

## **Dennis W. Reep, PE**

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The Tongue River Watershed, located in northeastern North Dakota, experienced significant snowmelt runoff and a subsequent basin-wide rainfall in 2013. The events led to auxiliary spillway flow in 6 of the 10 watershed dams, and created an emergent situation at Renwick Dam, the most downstream dam in the watershed and one which is in series with the remaining 9 dams.

After a significant spring snowmelt of up to 6 inches of snow water equivalent engaged the second stage of the principal spillway, a series of rainfall events occurred over a period of a few days before the entire flood pool could be evacuated. This series of rainfall events culminated with a rainfall in the basin of up to 7 inches over a 36-hour period.

The combination of hydrologic occurrences pushed the reservoir behind Renwick Dam to the verge of going over the auxiliary spillway, a vegetated earthen spillway that had never engaged in its 50 years of existence. The underlying materials of the spillway are comprised of poorly graded sands (SP in the USCS), and thus were extremely susceptible to erosion. This led to the unique response of constructing a temporary dike across the auxiliary spillway, thereby relying on the storage in the reservoir up to the top of the dam to contain the runoff.

The presentation will focus on the precipitation events leading to the situation, the unique response to the conditions present at Renwick Dam, and the results of the decisions made.

## **2013 RECORD SNOWFALL AND PRECIPITATION IN WESTERN SOUTH DAKOTA**

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The blizzard of October 2013 was devastating to many livestock producers, ranchers, and communities with over 21,000 cattle and over 1600 other animals (sheep, horses and buffalo) that perished. Power and utility services were down for several days. The economic impact of this record blizzard has yet to be determined, and may never be fully known, as there are many secondary or indirect impacts that are difficult to calculate.

This event is meteorologically and hydrologically notable not only for the timing, having occurred on October 4-5 when most cattle were still out on pastures, but also because of the large amount of moisture during this and other events in the fall season of 2013. It was a record setting event, month, and year for some locations in western South Dakota. This presentation will review many of the precipitation records that were established in 2013 across the region, including a preliminary state annual precipitation record at Lead, SD of 49.52". In addition, the October 4-5 blizzard event will be compared to historical fall blizzards, and also to climate projections for the region in an effort to ascertain the likelihood of similar events occurring in a future climate.



# **THE “SHUTDOWN” BLIZZARD AND FLOODING OF OCTOBER 2013 IN WESTERN SOUTH DAKOTA**

**Melissa Smith**

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From October 1 through 16, 2013, most routine operations of the federal government were shutdown when Congress failed to appropriate funds or pass a continuing resolution for fiscal year 2014. During this time, three large storm systems moved across the Rockies and brought significant precipitation to western South Dakota and the Black Hills. The first storm system was a crippling blizzard that brought 12–24 inches of snow to the plains with four to five feet in the Black Hills. Liquid equivalent precipitation greater than four inches was common. Much warmer air followed this storm and allowed the snowfall to rapidly melt. The initial snowmelt caused streams to rise and dry creeks to begin to flow; however no flooding was reported due solely to this event.

Another strong storm moved across the northern plains late Thursday October 10 and Friday October 11. This was a warmer system and produced widespread rainfall, with snow only in the higher elevations of the northern Black Hills. Additional liquid accumulations of 1.5–3.5 inches were common. This additional rainfall, combined with the melting snow, caused flash flooding in Keystone on October 11 and caused several smaller creeks and streams across western South Dakota to approach or exceed flood stage from October 11–17.

A third storm system tracked through the northern plains from October 13–15. This system brought an additional one to two inches of rain to the South Dakota plains and several inches of snow to the Black Hills. This storm system resulted in additional flooding and exasperated the flooding that began on October 11.

As the furlough ended, the flooding subsided. These storm systems shared several unique characteristics that this presentation will discuss. The factors that came together to produce widespread flooding in October 2013 also will be presented.

# REVISITING STATISTICAL ASPECTS OF THE HYDROMETEOROLOGICAL HAZARDS IN BANGLADESH

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Natural hazards are the extreme unfavourable occurrences resulting from natural processes that include floods, landslide, cyclones and other geologic hazards. Bangladesh has demonstrated regular natural disasters with significant damage to the properties and death toll over the past decade as presented in many literatures. Bangladesh, the world's eighth most populous country has a tropical climate with mild winter, and hot-humid summers. This study aims to review and analyze hydrological and meteorological natural disasters in Bangladesh. The objective was achieved by reviewing several case histories of extreme occurrences and analyzing historical data of annual rainfall, extreme rainfall events, annual maximum discharges by major rivers and cyclonic events based on reported cases. The review analysis revealed the major extreme hydrological events commonly occurred during monsoon season and meteorological disasters commonly occurred during pre-monsoon and post-monsoon seasons. The Mann-Kendall static test showed the increasing trend of annual rainfall and extreme rainfall events of the country. Linear regression analysis showed observed annual rainfall and extreme rainfall events are increasing about 2.28 mm and 0.037 events per year respectively. Annual maximum discharge of the major rivers were also following increasing trend and the Ganges river was showing highest increasing rate about 980 m<sup>3</sup>/sec per year. Cyclonic events were found more frequent in recent years despite of having lower magnitude of maximum wind and storm surge height. This research provides a guideline to predict the frequencies and magnitude of upcoming natural disasters in Bangladesh.

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**WEDNESDAY, APRIL 9, 2014**

**SESSION 4P**

**4:10 – 5:30 P.M.**

**HYDROGEOLOGIC CHARACTERIZATION AND EROSION  
(PONDEROSA ROOM)**

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# **PERMEABILITY OF THE INYAN KARA GROUP IN THE SOUTHERN BLACK HILLS AREA**

**Perry H. Rahn**

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Fluvial sandstone channels in the Cretaceous Inyan Kara Group in western South Dakota have variable thickness and texture, causing variability of the hydraulic conductivity. Pumping tests in two 120-ft thick sandstones at a proposed in-situ leach uranium mine in the Dewey/Burdock area provide hydraulic conductivity data. The hydraulic conductivity in the upper sandstone (Fall River Formation) is 0.45 ft/day and the lower sandstone (Chilson Member of the Lakota Formation) is 1.56 ft/day. These data, along with the prevailing gradient of the potentiometric surface, are used to estimate the groundwater velocity. The average groundwater velocity for these two sandstones in the Inyan Kara Group is approximately 66 ft/year.

A groundwater velocity determination of 5,480 ft/year in the Inyan Kara Group near the Dewey/Burdock site was based on 1963 tritium data (Gott et al., 1974). This value seems very high, but may indicate fast groundwater movement through very permeable units or through fractures.

An important environmental consideration following the abandonment of this proposed uranium mine is that the groundwater will migrate downgradient and most likely contain a high concentration of dissolved uranium (with daughter products radium and radon) and selenium. The rate of movement of these elements would be less than the groundwater velocity because of retardation associated with geochemical reactions related to changes of pH and oxidation/reduction potential.

# **HYDROGEOLOGIC CHARACTERIZATION OF THE BEAR LODGE RARE EARTH ELEMENT PROJECT, WYOMING**

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Rare Element Resources, Inc. (RER) is planning to extract Rare Earth Elements (REE) from the Bear Lodge Project located in northeastern Wyoming. The resources are located within a Tertiary carbonatite alkaline intrusive complex. A key component in the permitting and development of the project is the hydrogeologic characterization of the ore-bearing units and potentially affected hydrologic systems. A thorough understanding of the site hydrogeologic system is critical to many aspects of the project, including mine dewatering, appropriation of water supply, and monitoring and protection of surface water and groundwater.

The hydrogeologic characterization is used to develop a conceptual model of site conditions. The conceptual model supports the development of numerical models used to evaluate probable hydrologic consequences (PHCs) of the proposed REE mine. The results of the PHC analysis will be used to assess the impacts to groundwater quantity and quality, surface water/groundwater interactions, water rights and to identify preventative and remedial measures to minimize those impacts.

Over forty monitor wells have been installed in the Project Area to support the hydrologic characterization efforts. Methods used to evaluate the hydrogeologic system include single and multi-well pumping tests, long-term water level monitor utilizing dedicated pressure transducers in monitor wells and manual water level measurements, water quality sampling, coring of exploratory borings, and construction of hydrologic transects across streams/drainages. A weather station within the Permit Area provides key precipitation data.

Several distinct hydrostratigraphic units are identified within the proposed mine permit area including the Alluvial, Tertiary Sedimentary (TS), Tertiary Intrusive (TI) and Paleozoic Units. The groundwater flow regime is dominated by fracture flow within the TI Unit. The Alluvial Unit is primarily limited to the major surface drainages of the area. The TS and Paleozoic units generally have lower transmissivity than the TI unit but are still important because they are hydraulically downgradient of the proposed mining area.

## **SHORELINE EROSION RATES AND PROCESSES ALONG LAKE SHARPE NEAR LOWER BRULE, SOUTH DAKOTA**

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The U.S. Geological Survey in cooperation with the Lower Brule Sioux Tribe is monitoring shoreline retreat along the western boundary of Lake Sharpe near the Lower Brule, South Dakota. Lake Sharpe is a reservoir along the Missouri River impounded by the Big Bend Dam. Construction of the Big Bend Dam began in 1959 and reservoir filling was initiated in 1963. During 2013–14, operation of the hydroelectric plant at Big Bend Dam is reflected in a cycle of reservoir water levels lowering during weekdays and rising during the weekend. An analysis of aerial photos and topographic maps since 1966 indicates truncation of several shoreline spurs by 1976, and subsequent shoreline retreat (aerial photographs since 1991). Aerial photo analyses complement Light Detection and Ranging (LiDAR) surveys of recent bank erosion from 2011–2013 near Lower Brule which indicated erosion rates of up to 9 meters per year. Time-lapse cameras have been installed at three locations to qualitatively examine shoreline changes: the Lodge site approximately 4 kilometers (km) north of Lower Brule, the Playground site along the shoreline east of Lower Brule, and the Lagoon site approximately 1 km southeast of Lower Brule. Images were taken four times per day. Soils at these sites are the Opal-Chantier clay, Bullcreek clay, and Fairlo silt loam, respectively. The Lodge site has a more complex stratigraphy with aeolian deposits underlying the Opal-Chantier clay. Soil samples have been collected at each location to determine soil properties and strength. A goal of this research is to identify the key factors, such as reservoir operation, wave erosion, ice scour, shallow groundwater movement, and soil properties that influence shoreline erosion. Once identified, these results can be used to inform the selection and development of strategies to mitigate shoreline erosion.

# **LEACHING CHARACTERISTICS OF RECYCLED CONCRETE AGGREGATE USED AS HIGHWAY BASE**

**Bora Cetin**

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Environmental suitability of seven different Recycled Concrete Aggregates (RCAs) was studied. Four different laboratory leaching tests were conducted: Water Leach Test (WLT), Synthetic Precipitation Leaching Procedure (SPLP), Toxicity Characteristic Leaching Procedure (TCLP) and pH-dependent leaching tests. Leaching behavior of Ca, Cr, Cu, Fe and Zn from RCAs were observed. The effects of pH, curing time, freeze/thaw cycles, liquid-to-solid ratio, particle size and atmospheric exposure on the leaching behavior of these elements were investigated.

Increasing curing time caused soil aggregation and generally yielded a decrease in pH and concentrations of elements. Exposure to atmosphere increased carbonation of the RCA material and decreased the pH, Ca and Cu and increased Cr and Fe. Freezing and thawing of RCA led to self-cementing and decreased pH, Ca, Cu, Fe concentrations while it caused Cr concentrations to increase slightly. Increasing the liquid-to-solid ratio decreased leaching of elements significantly due to the dilution of leached elements in the aqueous solutions. Furthermore, it was determined that there were significant differences in the leached concentrations of elements measured in three different laboratory tests, i.e., CTCLP > CSPLP > CWLT. Ca showed cationic leaching patterns while Cr, Cu, Zn and Fe showed amphoteric leaching patterns in pH-dependent leaching tests. Tests results indicated that leached Zn concentrations were below the detection limits at pH > 5. Leached concentrations of Ca, Cu, Cr, and Fe were mostly below the Environmental Protection Agency Maximum Contaminant Levels (EPA MCLs) indicating that use of these RCAs as a sub-base/base layers in highway is environmental friendly.

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**WEDNESDAY, APRIL 9, 2014**  
**POSTER SESSION AND EVENING SOCIAL**  
**5:30 – 7:30 P.M.**

**(RUSHMORE G ROOM)**

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# COMPARING NUTRIENT DEMANDS AND METABOLISM IN TWO LAKE OUTLET STREAMS CONTAINING *DIDYMOSPHENIA GEMINATA* IN GRAND TETON NATIONAL PARK

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*Didymosphenia geminata* (Didymo) is a freshwater alga native to North America that was historically quite rare and found in clear, cold, oligotrophic streams. However, over the past two decades, an abundance of Didymo and its extracellular stalks have been reported across the U.S. Didymo forms benthic mats of stalk material that can cover an entire stream up to 20 cm thick. Yet, little is known regarding the effects of Didymo mats on stream ecosystem functions like nutrient uptake and metabolism. We will examine two streams in Grand Teton National Park, both of which are lake outlets and within 15 km of each other, but display varying amounts of mat coverage—Lake Creek has thick mats covering >70% of substrates for more than 1 km, whereas Taggart Creek contains Didymo with minimal mat development. We will measure whole-stream metabolism in order to quantify the effects that Didymo mats may have on primary productivity and ecosystem respiration. Additionally, we will measure nutrient uptake of ammonium, nitrate and phosphate, to investigate how Didymo mats may change the availability of nutrients like N and P, which all biota depend on for growth and reproduction. Disturbances by Didymo mats to stream metabolism and nutrient uptake may cause ecological and economic impacts, such as altering food web dynamics, loss of species diversity, and shifting of energy pathways.

# **BENTHIC MACRO-INVERTEBRATE DIET SELECTION IN RAPID CREEK, SOUTH DAKOTA**

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*Didymosphenia geminata*, a freshwater diatom, can form mats of extracellular stalk material that cover one hundred percent of the stream substrate up to twenty centimeters thick for several kilometers. *D. geminata*'s growth can greatly disrupt the function and processes of a stream ecosystem and is often labeled as a nuisance species in United States. Benthic macro-invertebrates (BMI) in Rapid Creek, SD, shift from larger BMI taxa towards smaller within *D. geminata* mats, but total BMI abundance increases. BMI play a key role in food web dynamics and energy flow in fluvial ecosystems; however, the effects of *D. geminata* on diet selection and foraging behavior of BMI is less clear. Our hypothesis is that there will be a shift in the composition of BMI's diet when *D. geminata* is a major constituent of the benthic resources present in the stream. We will quantify diet selection and resource availability of BMI in Rapid Creek through monthly BMI, epilithon, particulate organic matter and seston collections. With this data, we will compare diet selection behavior against the total available resources. The resulting shift towards *D. geminata* consumption in the diet of BMI can dramatically alter the food web dynamics of Rapid Creek. Our goal is understanding BMI foraging behavior in the presence of *D. geminata* mats and develop a base for understanding the effects of *D. geminata* on food web dynamics.

# **EFFECTS OF *D. GEMINATA* ON GROWTH RATES AND SECONDARY PRODUCTION OF BENTHIC MACROINVERTEBRATES IN RAPID CREEK, SD**

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*Didymosphenia geminata* (*D. geminata*) is a nuisance species of freshwater algae that can produce copious amounts of stalk material covering up to 100% of stream substrates. *D. geminata* has been documented in Rapid Creek, SD, since the early 2000s and has altered the benthic macroinvertebrate (BMI) assemblage. Through declines in species richness and abundance in some taxa, as well as a general shift in the composition of the assemblage, the consequences of these changes may affect other trophic levels. Secondary production estimates involve energy flow of each taxa in the assemblage and that energy is used for many major biological processes such as growth creating tissues, respiration, reproduction and excretion. We will estimate growth rates and secondary production of BMI assemblages, starting with Chironomids and Oligochaetes, as these taxa thrive in thick *D. geminata* mats. With data on size frequencies, biomass and secondary production we can begin to understand how *D. geminata* mats alter stream food web dynamics. Many organisms both aquatic and terrestrial, are dependent on BMI as a food source, thus, shifts in BMI abundance and assemblage dynamics due to *D. geminata* mats may yield alterations in other trophic levels.

# **CALIBRATION OF AGRIDRAIN CONTROL STRUCTURE BY USING GENERALIZED “V” NOTCH WEIR EQUATION FOR FLOW MEASUREMENT**

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Subsurface drainage control structures are used in drainage water management systems to convey water, control and measure the discharge, and raise the outlet elevation. The upstream water level of the control structure is managed by adjusting the height of an over fall spillway inside the structure. Some control structure designs utilize removable boards as spillway, while other designs utilize PVC pipe oriented vertically. The water level is managed by adding or removing boards or inserting pipes of different lengths.

By installing triangular weirs inside the control structure, the flow rate can be estimated from the thickness of the sheet of water flowing over the spillway (nappe). The basic principle is that discharge is directly related to the water depth, or head, above the crotch of the weir. Due to the design of triangular weirs, small changes in discharge cause large change in thickness of the nappe which allow more accurate flow measurement than rectangular weir.

We conducted a bench-scale experiment to calibrate a water level control structure from the commercial company Agridrain. We used a generalized V notch equation relationship  $Q = C \cdot H^{(-5/2)}$ , where C is a discharge coefficient specific to the angle of the “V”, Q is the discharge and H is the head. By utilizing an independent flow measurement gauge and pump, we measured the head for flow rates increasing incrementally from 4 l/min to 114 l/min using a pressure transducer. For the experiment, we used a control structure with an inside width of 152 mm.

Based on the initial measurements, we developed the following preliminary equation:  $Q = 1.5501 H^{2.202}$ , where Q is the flow rate in l/min and H is the thickness of the nappe in cm. The equation was developed using power regression analysis with an  $R^2$  of 99%. This equation will be used to convert the depth of water in the control structures used at our drainage research field sites into flow rate, without installing any additional flow measurement devices.

# **A STATE-WIDE GROUNDWATER RECHARGE ESTIMATE FOR SOUTH DAKOTA AND THE BLACK HILLS IN WYOMING**

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Rapidly increasing demand for groundwater in South Dakota requires a better understanding of groundwater availability. For this reason the U.S. Geological Survey (USGS) South Dakota Water Science Center, in cooperation with the National Park Service, the Black Hills National Forest, and the West Dakota Water Development District, began a computer modeling project for groundwater flow in Black Hills aquifers. The model will help assess the effects of current or future groundwater extraction or drought on regional groundwater availability. Aquifer recharge from precipitation is one of many inputs for this groundwater model. Using the USGS Soil-Water-Balance (SWB) model, groundwater recharge from precipitation for the entire State of South Dakota and the Black Hills area in eastern Wyoming was calculated. The SWB model uses a modified Thornthwaite-Mather soil-water-balance method to calculate spatially distributed recharge values for rectangular grid cells. The recharge value for each grid cell is the difference between the change in soil moisture and the sources and sinks over a daily time step. The model calculates soil moisture using intermediary values including precipitation minus potential evapotranspiration, accumulated potential water loss, actual evapotranspiration, and soil-moisture surplus and deficits. Model inputs included daily precipitation and air temperature, land cover, hydrologic soil group, available soil-water capacity, and hydrologic run-off flow direction data. Recharge values for the study area were calculated at a 1-kilometer (km) spatial resolution for calendar years 1981 to 2011. The estimated 30-year average recharge for the study area ranged from more than 8 inches per year (in/yr) in some parts of the Black Hills to less than 0.1 in/yr in southwestern South Dakota. To determine the average annual recharge to the Madison and Minnelusa aquifers, which are important groundwater resources in western South Dakota, the study area was overlain with the lateral extents of the recharge areas, which included overlying surficial deposits. Using this method, the estimated 30-year average recharge from precipitation to the Madison and Minnelusa aquifers was calculated as 3.11 and 2.17 in/yr, respectively. The SWB model routes excess water in each cell to down-slope cells that can accept this routed water as recharge if the soil is not fully saturated. This function, however, was not used because it causes large inaccuracies in a model with a resolution as coarse as 1 km. The sensitivity of this flow-routing function on estimated recharge values was tested by using high-resolution (30-meter) models.

# **VERIFICATION OF A HEAVY PRECIPITATION EVENT USING THE SDSMT REAL-TIME WRF FORECASTING SYSTEM**

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In September 2013, heavy rainfall and catastrophic flooding affected several counties along the Front Range in Colorado. Nearly 20 inches of rain fell in Boulder County in five days, which is close to the annual average. The flooding had economic, ecological, and hazardous impacts to the area. While the precipitation forecasts for most of the area were accurate, a majority of the ensemble models vastly underestimated the precipitation amounts in Boulder County.

Forecast verification, or evaluation, is used to identify model strengths and weaknesses in order to improve forecast accuracy. This is done by comparing model output to actual observations. The Model Evaluation Tools (MET) verification package was developed at the National Center for Atmospheric Research Developmental Testbed Center using output from the Weather Research and Forecasting (WRF) modeling system. It was developed to encourage consistent verification among WRF users. The package consists of a set of highly configurable tools used to create statistical based model verification.

The MET package will be used to evaluate output from the South Dakota School of Mines and Technology real-time WRF model for the Boulder flood using both gridded and point precipitation observations from the event. This will identify strengths and weaknesses of the model's precipitation forecasts, and provide a basis for which the model can be improved. This is the test case by which the SDSMT real-time system will be assessed for its current operational use over the Rapid City County Warning Area, the study period for which will be for the 2014 calendar year.

# INFLUENCES ON GROUNDWATER QUALITY IN PRECAMBRIAN CRYSTALLINE AQUIFERS OF THE CENTRAL BLACK HILLS

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In the spring and fall of 2013, students and faculty members from the Department of Geology and Geological Engineering, at South Dakota School of Mines and Technology, conducted a water quality study of the Precambrian crystalline aquifers of the central Black Hills, Pennington County. Samples collected from ninety-one private water wells in the Hill City-Keystone-Pactola Lake area were analyzed for arsenic, calcium, magnesium, hardness, iron, sulfate, nitrate, and bacteria by MidContinent Testing Laboratories of Rapid City. Data are also included from twenty six public water systems (DENR data base) and thirty seven wells from the USGS NWIS data base. The latter samples were analyzed for only part of the set established in our study. Density cloud maps were produced in ArcGIS 10.2 to show spatial trends of the results. The scope of the study will expand in the subsequent two years to cover most of the Precambrian bed rock area of Pennington County. The studies are funded by the West Dakota Water Development District.

Results: Relative to EPA standards for public wells, the following was found: 1) Arsenic – 28% of 114 wells were above the 10 µg/L level; 2) Hardness – 53% of 123 wells exceeded the 150 mg/L level; 3) Iron – 31% of 118 wells were above the 0.3 mg/L level; 4) Sulfate – four of 131 wells exceeded the 250 mg/L level; 5) Nitrate – five of 134 wells were above the 10 mg/L level; 6) Total coliform – 57% of 109 wells tested positive; 7) Fecal coliform - 18% of 96 wells tested positive.

Interpretation: 1) Arsenic appears to have a geographic relationship with areas of previous mining exploration and activity. 2) Iron concentration patterns are generally similar to those of arsenic in known mining areas. 3) Hardness values vary throughout the study area, but are generally higher from metagraywacke parent rock. 4) The four samples above the recommended EPA limit for sulfate are in the Keystone area. 5) Total and fecal coliform occur in widely distributed clusters. 6) Nitrate exceedences are spatially associated with clusters of fecal and total coliform.

# **ASSESSING GROUNDWATER AVAILABILITY OF THE WILLISTON AND POWDER RIVER STRUCTURAL BASINS, NORTHERN GREAT PLAINS**

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Groundwater availability in the lower Tertiary, Upper Cretaceous, and glacial aquifer systems in the Williston and Powder River structural basins is currently being assessed by the U.S. Geological Survey (USGS). The Williston structural basin is located in parts of North Dakota, South Dakota, and Montana in the United States and Manitoba and Saskatchewan in Canada. The Powder River structural basin is located in parts of Montana and Wyoming. A large amount of water is needed for energy development in these basins, and the primary accessible aquifers are glacial sand and gravel aquifers and the lower Tertiary and Upper Cretaceous aquifer systems. These aquifers commonly are the shallowest, most accessible, and in some cases, provide the only potable groundwater within the Northern Great Plains aquifer system. The USGS currently is conducting a 4-year groundwater availability study of these regional aquifer systems, which will include conceptual and numerical models of groundwater flow. Both of these models include a quantification of recharge and discharge components. In addition, the numerical model will be used to assess groundwater sensitivity to water withdrawals and climatic effects.

The components of groundwater recharge consist of recharge from direct precipitation on aquifer outcrops, infiltrating streams, and excess irrigation water; components of groundwater discharge to the land surface consist of discharge to streams and well withdrawals. Recharge from direct precipitation was estimated by using a soil-water balance model, with additional estimates from the water-table fluctuation and chloride mass-balance methods. The interaction between groundwater and surface water was quantified by analyzing streamflow records, using hydrograph separation methods, and implementing a water-budget analysis for major reservoirs in the study area. Groundwater withdrawals were quantified by analyzing Federal and State well databases and assessing previously published information. Estimated stream recharge accounts for 74% of total recharge, and direct precipitation and excess irrigation account for 23% and 3% of recharge, respectively. Discharge from groundwater is dominated by discharge to streams (96%) and well withdrawals (4%).



# **DEVELOPMENT OF ELEVATION DERIVATIVE DATASETS FROM USGS HIGH-RESOLUTION DIGITAL ELEVATION DATA NEAR SIOUX FALLS, SOUTH DAKOTA**

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Digital elevation data (also known as “digital elevation models” or DEMs) can be used to calculate flow direction and many other derivative datasets. These datasets include synthetic drainage networks, watershed boundaries, and numerous other applications. In recent years, lidar-derived DEMs have become available for many parts of the Nation, allowing for the creation of elevation data and derivatives that include information useful at local scales.

In cooperation with the City of Sioux Falls and the State of South Dakota, the USGS has processed high-resolution elevation data retrieved from the USGS National Elevation Dataset covering three watersheds in eastern South Dakota. “Selective drainage” methods developed by the USGS Earth Resources Observation and Science (EROS) Data Center have been applied to determine locations of culverts and bridges that disrupt modeled flow directions across the elevation surface. Supplemental linear datasets and non-contributing “sinks” have been created to model surface-water flow. This combined information has been integrated with the elevation surface to create a flow-conditioned DEM. This dataset has been used to develop a detailed synthetic drainage network and improved watershed boundaries.

# **EFFECT OF CLIMATE VARIABILITY ON CORN YIELD IN EASTERN SOUTH DAKOTA**

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Characterizing climate impacts on corn yield is a continued effort aiming at improving the technologies and management strategies of farming, minimizing adverse climate effects and maximizing positive climate effects on yields. South Dakota is one of the major corn producing states in the U.S., however, previous studies of climate effects on corn yield in the state used yields and climate records that were less than a decade and were not specifically on South Dakota. Even though results of those studies pointed to primary meteorological factors influencing corn yields, some questions remain including better adaptation to environmental stresses by newer corn hybrids. In this study, the effect of growing season climate conditions (rainfall, air temperature, solar radiation) on the growth and yield of corn in eastern South Dakota are examined using unique long term (1950-2012) data-set for both corn yield and climate. Other objectives of the study are to quantify the impact of irrigation on corn yield and to develop a relationship between corn yield and Aridity Index (AI). County level corn yields are obtained from the USDA-NASS website and climate data from the South Dakota county weather stations. Preliminary results show positive correlation between corn yield and June, July, August total rainfall both at the long term and decadal scale except for the 90s which showed a negative correlation for almost all the counties.

# **SUSTAINABILITY ASSESSMENT AND DESIGN CRITERIA FOR IRRIGATION FOR LESOTHO**

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Food insecurity is a growing global issue especially in drought affected countries. Among the technologies available, irrigation maybe one of the best ways to increase and stabilize food production. Irrigation plays several important roles in food production including: replenish of soil moisture, enhancing plant growth, salts leaching and frost protection. Lesotho is one of the countries that are most severely affected by food insecurity due to low yields, severe droughts, frost, hail and unexpected heavy rains and land degradation. At present, Lesotho is therefore forced to seek food aid from the international communities in order to feed its population. Despite Lesotho taken as a whole, has a relatively ample water supply, its topography, underdeveloped water distribution network and climate variability remain a large challenge in widespread implementation of irrigation. The literature describes different irrigation systems but the gap remains in connecting the topography and water distribution for many areas to install irrigation systems. Therefore, the objective of this research is to explore, assess and provide design criteria for effective, low cost, environmentally friendly irrigation systems that can work in Lesotho based on varying topography and water distribution. Our approach uses weather data from six closest South Africa weather stations surrounding Lesotho to compute evapotranspiration to estimate crop consumptive use and irrigation water requirements, and map and design irrigation system for a particular area. Our results show that the evapotranspiration ranges from 1 mm/day to 7 mm/day while precipitation ranges from 0 to 60 mm/day varying throughout the year indicating the requirement for irrigation. Depending on the capability of the irrigation system in terms of topography and water distribution, we will suggest irrigation system design criteria and recommendations for a particular area. This approach would provide new information and decision support for the ongoing plans for designing for effective, low cost and environmentally friendly irrigation system to help increase food security in Lesotho.